

National Aeronautics and Space Administration

# Goddard Tech Trends

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tech trends

## Carrying on the Tradition

### Instrument to Search for Signs of Cosmological Inflation Investigated

Scientific results from the Goddard-developed Cosmic Background Explorer (COBE) and the Wilkinson Microwave Anisotropy Probe (WMAP) helped to cement the big-bang theory of how the universe was created, resulting in a Nobel Prize for one of the principal investigators. A group of Goddard scientists now believes the technology exists to build a new instrument to determine whether the infant universe expanded from subatomic scales to the astronomical in a fraction of a second after its birth.

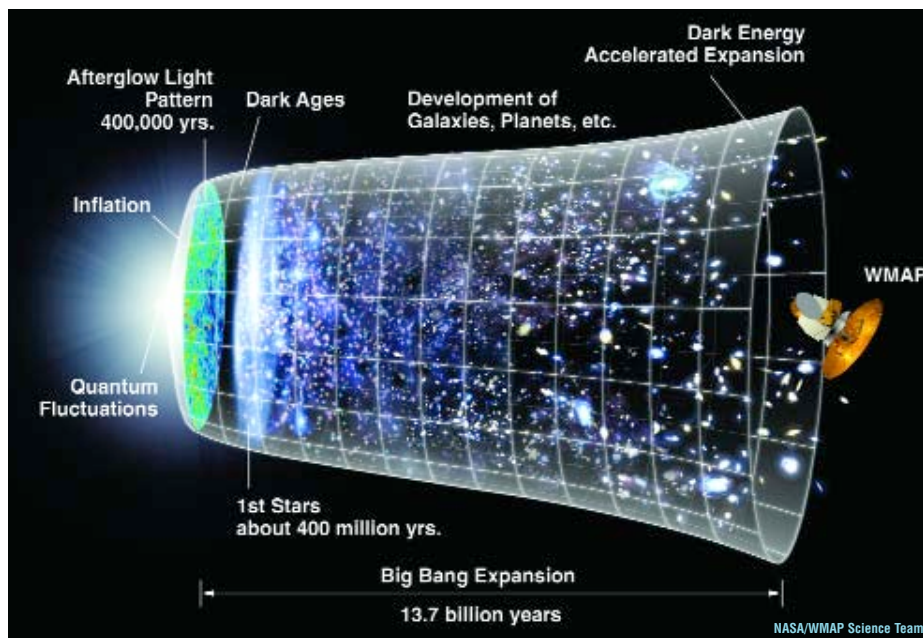
With Headquarters and Goddard Internal Research and Development (IRAD) funding, Principal Investigator Harvey

Moseley and his team are developing a concept for an instrument that would search for signs of cosmic inflation in the background radiation, the remnant light from the first moments of the universe's creation that bathes the sky in all directions.

Considered a staggering idea just 20 years ago, the inflation theory postulates that the universe expanded far faster than the speed of light and grew from subatomic to golf-ball size almost instantaneously. During this growth spurt, microscopic fluctuations in the density of the cosmos were amplified, ultimately leading to the stars and galaxies that fill the universe today.

### Searching for B-Mode Polarization

In particular, the team is advancing technologies for large arrays of super-sensitive detectors and other components



*This graphic shows the timeline of the universe. Although the universe has expanded gradually over most of its history, scientists believe that it expanded from subatomic scales to the astronomical in a fraction of a second after its birth. Goddard hopes to build an instrument that would search for signs of this cosmic inflation.*

needed to build an instrument, called CMBPol, to detect a particular type of polarization signal — B-mode, in the parlance of cosmologists. “If we detect this pattern of polarization in the cosmic background radiation, it will give us the ‘smoking gun’ evidence that inflation did indeed occur,” said Dave Chuss, one of the co-investigators on the team.

While WMAP offered tantalizing evidence supporting the inflation theory, definitive proof still remains elusive without a new instrument, he added.

WMAP, the follow-on mission to COBE whose results earned Principal Investigator John Mather a Nobel Prize last year, studied the afterglow radiation in greater detail and provided more precise measure-

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## On The Cover:

*Goddard Principal Investigator Harvey Moseley is leading a team to advance technologies necessary to build a follow-on instrument to those flown on the Cosmic Background Explorer and the Wilkinson Anistropy Probe. Both helped to rewrite the astronomy books on how the universe was created. His instrument would search for signs of cosmic inflation, a theory that postulates that the infant universe expanded far faster than the speed of light after its creation. He is shown here with a timeline of the universe.*

Photo Credit: Anthony Gatling

## The Dust Busters

### Scientists Hope to Gather Measurements of the Moon's Dusty Environment

It won't be easy living and working on the Moon. On certain days each month, a veritable "dusty sleet" made up of irregularly shaped, razor-sharp dust grains traveling at hurricane-like speeds could pelt the astronauts, possibly damaging their spacesuits and the robotic machinery they will use to establish their permanent outposts.

These ultra-tiny dust grains — formed by millions of years of meteorite impacts that repeatedly melted rocks into glass and then broke the glassy rocks into powder — are highly electrostatic. Because of these issues, NASA has ranked lunar dust as among the top hazards to mitigate before sending human astronauts to the Moon for extended stays. However, before engineers can design a detailed dust-mitigation strategy, NASA needs to better understand the physics that drive the phenomenon, many dust experts believe.

Goddard scientist Bill Farrell is one of them.

He and his colleagues recently won research and development funding to carry out feasibility studies on hardware requirements for a follow-on instrument to the Lunar Ejecta and Meteorites (LEAM) instrument, which Goddard dust pioneer Otto Berg developed for the Apollo 17 mission. With this funding, Farrell is investigating the development of a higher-precision instrument that would help identify the processes that create the dusty environment and accelerate the movement of dust grains on and above the surface.

"It's not about just dust," he says. "It's an environmental system question. If you understand the system, you can do predictions and develop ways to better alleviate, mitigate, or simply avoid the dust hazard."

#### Electrostatic Clinging

Scientists now know that lunar dust clings because of its varying shapes and jagged edges that hook into objects like microscopic burrs. However, another reason for the tenacious clinging is the dust's electrostatic charge.

On the day side of the Moon, harsh, unshielded ultraviolet radiation from the Sun kick electrons out of the upper layers of the lunar regolith or soil, giving the surface of each dust particle a net positive charge. This positive charge builds up until a small fraction of the looser grains, some measuring one micrometer or smaller, are repelled and lofted

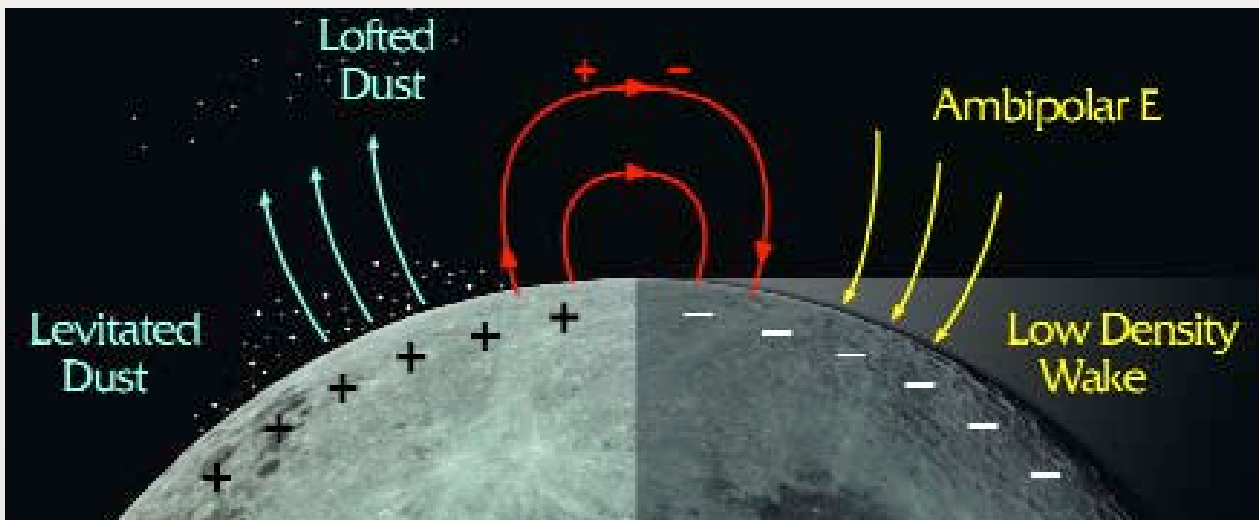
from meters to kilometers high — a phenomenon observed by the Apollo astronauts and the Lunar Surveyor missions. They eventually fall back, but the process repeats itself, creating an atmosphere of vertically moving dust particles.

On the dark side of the Moon, the situation is a little different. Plasma currents from the Sun also charge the lunar surface, but negatively. The situation gets interesting where the two sides meet at the terminator — the

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*"Dust is going to be the environmental problem for future missions, both inside and outside habitats."*

— Harrison "Jack" Schmitt, geologist and Apollo 17 astronaut



On day side of the Moon, dust particles are positively charged. On the dark side, they are negatively charged. The situation gets interesting where the two sides meet — the moving line between lunar day and night. The transition could create more complex and stronger electric fields, further accelerating the dust grains.

## Returning to the Moon

### *Goddard Team Presents Lunar-Lander Concepts to All-Star Panel*

Although the Goddard Space Flight Center is better known for developing and managing science missions, a handful of employees recently received Headquarters funding to develop a concept for landing astronauts and cargo on the lunar surface.

The 25-member Goddard-led team, which included some members from Glenn Research Center and Johnson Space Center, presented their ideas to a panel of former and current NASA officials, including former astronauts John Young and Joe Engle, and Owen Morris, who headed the Apollo Lunar Lander program in the 1960s.

#### Exposure to Apollo Veterans

“For many of the Goddard team members, the most rewarding part of this study effort was the deeper exposure it provided to the concepts, accomplishments, and — most importantly — some of the still active veterans of the Apollo program,” said Lloyd Purves, a system engineer on the concept study. “What made the lunar lander particularly interesting is that, in some ways, it can be seen as the supreme engineering challenge on Apollo. The Apollo lander module had no precedent. Nothing before had taken humans to and from the lunar surface and nothing has since.”

The Exploration Systems Mission Directorate is expected to use and refine some of the ideas in further studies. The images — some created by intern students who participated in Goddard’s “skunkworks” effort — show a few of the ideas that the Goddard team presented.

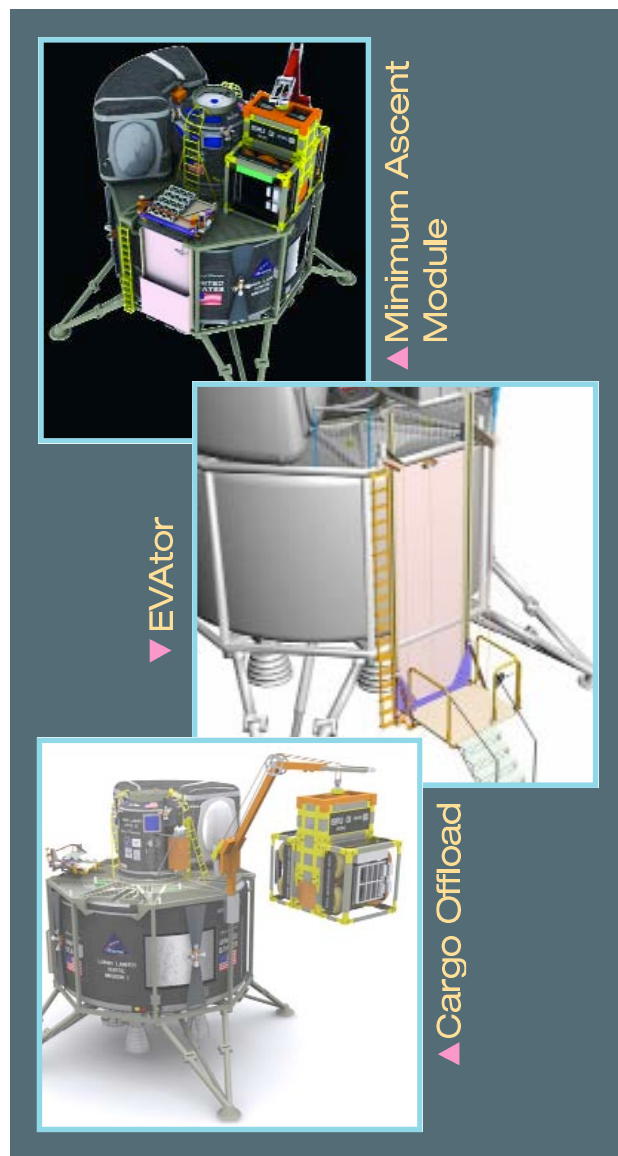
#### Lander Concept: Minimum Ascent Module

Unlike previous concepts that combined an ascent vehicle with a habitat, the Goddard team proposed a vehicle for only transporting crew and cargo to the surface. This way, the crew could ferry more cargo. The proposed vehicle would weigh 3,300 kg (2,315-lb.) and contain 11.1 cubic meters (392 feet) of pressurized volume, capable of taxiing up to four astronauts wearing Mark III spacesuits. It also would feature an external cargo area, inside storage space, windows, multiple exit points, including a full-size door, and a dust-collection system. Lunar samples and avionic and life-support equipment would be stored beneath the floor.

#### EVAtor

To keep astronauts from descending directly into the lunar dust, which can be as sharp as razor blades, the Goddard team created an elevator or “EVAtor” system that would lower two astronauts and equipment from the top of the 6-meter-tall (20 feet) module to the surface. Equipped with a control panel, platform, fixed rails, cable supports, and handrails, the EVAtor also would include a set of steps that would deploy directly to the surface. The

team considered a range of options, including a scissors lift, a rappelling device, and even a Ferris Wheel-like rotary lift, but settled on the elevator system after consulting with astronauts who preferred the elevator system.



#### Cargo Offload

To offload up to 21 metric tons (46,000 lbs.) of cargo to the lunar surface, the Goddard team examined a single crane and a direct-to-surface (D2S) method. Although the team determined that both would meet NASA requirements, it found that the D2S system was more efficient and less risky under certain conditions. The system would work simply by tilting the cargo and allowing the cushioned shipping containers to fall directly onto the surface. Due to the Moon’s low gravitational pull, the impact would be no more severe than if someone pushed a padded container off a kitchen table. ♦

Four Goddard principal investigators have earned berths on a high-risk, experimental satellite — MidSTAR-2 — now being developed by midshipmen at the U.S. Naval Academy in Annapolis, Md.

The four experiments and a fifth alternate were selected as part of Goddard's FY 2007 Internal Research and Development (IRAD) program and are designed to advance the technology readiness level of innovative scientific instruments that the principal investigators could then propose later in future NASA mission opportunities (see box for a description of each).

"This is a program where everyone wins," said Goddard's MidSTAR Program Manager Dan Powell. "Students get an opportunity to build and integrate a satellite bus and our principal investigators get a free ride."

### General-Purpose Bus

MidSTAR is a general-purpose satellite bus constructed primarily of off-the-shelf, plug-and-play components assembled and integrated by students, who will receive some instruction and assistance from experienced Goddard engineers, Powell said. It accommodates a range of small space experiments and instruments each weighing no more than 6 lbs. and using no more than 6 watts of power. Goddard's instrument teams are expected to have their payloads finished by 2009 for integration onto the satellite.



*A Delta-4 rocket similar to the one pictured here will deploy the MidSTAR-2 satellite.*

According to current plans, the MidSTAR platform is expected to launch on a military-provided Delta 4 rocket in 2010. After reaching its medium-Earth orbit, MidSTAR and its instrument payload will spend 2 years in orbit.

Though Powell conceded that the opportunity is risky for principal investigators, the benefits far outweigh the risks. "We stand to gain a substantial scientific return." ♦

## Payloads Hope to Advance Technology Readiness Levels

The Office of the Chief Technologist selected four science instruments and a fifth alternate to fly on MidSTAR-2 in 2010. They include:

### *MINI-ME (Miniature Imager for Neutral Ionospheric Atoms and Magnetospheric Electrons) — Principal Investigator Michael Collier*

MINI-ME is a low-energy neutral atom and electron imager that could reveal more about the global nature of the solar wind and its interaction with solar system planets. One day, the imaging technology also could help explain why Venus lost its water and whether conditions at Europa, Jupiter's moon, could support life.

### *PISA (Plasma Impedance Spectrum Analyzer) — Principal Investigator Douglas Rowland*

PISA will accurately measure electron density and temperature in Earth's upper atmosphere — data needed to understand the ways that solar wind produce complex structures and turbulence at high altitudes. These structures can scatter radio waves, making their use for navigation and communication difficult when the Sun is active.

### *Remote Sensing of the Thermospheric Temperature — Principal Investigator John Sigwarth*

This revolutionary imager will remotely sense the temperature of Earth's thermosphere. Understanding this region is important for determining the effects of atmospheric drag on low-altitude spacecraft.

### *The Gamma-Ray Burst Polarimeter — Principal Investigator Keith Jaboda*

This experiment will primarily provide flight heritage for several components of a new X-ray polarimeter. X-ray polarimetry can reveal much about the neighborhood of neutron stars or black holes — information not available from imaging, spectroscopy, or timing.

### *Compact, Combined Neutron, Gamma-Ray and Particle Radiation Detector — Principal Investigators Jack Trombka and Ann Parsons*

This new device packages a gamma-ray spectrometer with a neutron counter and particle detector — a combination that could reveal more about the chemical abundances found on the surfaces of other solar system objects. This is the alternate payload.

## Tradition... *Continued from page 2*

ments of the tiny temperature differences in the background light. These differences varied by about a millionth of a degree and pointed to density differences that eventually gave rise to the stars and galaxies seen today.

It also measured E-mode polarization of the microwave background radiation, which pointed to the time when the light from the first stars ionized hydrogen atoms and liberated electrons from protons. At this point, the first stars — the predecessors to all subsequent generations of stars — were fully formed. WMAP, with its measurements of E-mode polarization patterns and its detailed temperature map, concluded that the first stars formed about 400 million years after the big bang.

While WMAP detected E-mode polarization patterns, the other type of polarization — B-mode — remains below its sensitivity threshold. This remaining piece to the inflation puzzle is what CMBPol would be designed to find. With this measurement, scientists could investigate the very first instants of the history of the universe and obtain the energy scale of inflation.



*Members of the CMBPol instrument team include (from left to right) Dave Chuss, Wen-Ting Hsieh, Thomas Stevenson, George Voellmer, Harvey Moseley, Ed Wollack, Kongpop U-Yen, Nga Cao, and Elmer Sharp.*

### Technology Within Reach

Although Moseley says the technology is within reach, the detectors present a challenge. The polarization signal is at least 100 times fainter than the temperature signal picked up by COBE and WMAP. Therefore, the detectors must be sensitive enough to find the signal. "If we find the pattern, it will rule out all the other viable models" on how the universe behaved the first trillionth of a second after its birth, he said.

"We actually know a huge amount about the overall structure of the universe," Moseley said. "What we're trying to get at are the physics, the big-bang measurements so that we can limit the number of models. This is very good science." ♦

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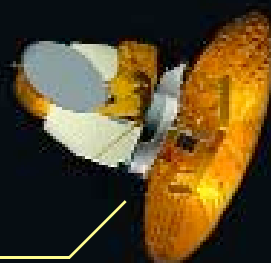
## Goddard's Cosmological Hall of Fame

The Cosmic Background Explorer (COBE) and the Wilkinson Microwave Anisotropy Probe (WMAP) — both developed at Goddard — have helped to rewrite the astronomy books on how the universe was created from an infinitesimally small point to the vast universe seen today. Here are a few of the spacecraft's most important accomplishments:



### COBE

- Studied the cosmic microwave background radiation and detected small variations in its intensity. These variations represent how matter and energy were distributed in the early universe. These differences — a little more matter here and a little less there — ultimately evolved into stars and galaxies seen today.
- Measured the temperature and energy distribution of the cosmic background radiation. The mission found that their distribution was in perfect alignment with theoretical predictions. This key discovery ruled out alternatives to the big-bang theory.



### WMAP

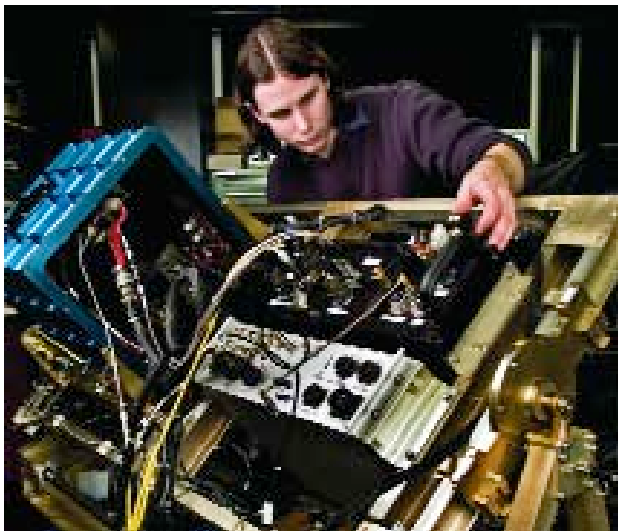
- Pegged the age of the universe at 13.7 billion years.
- Found that atoms first began to form in the universe 380,000 years after the big bang and that stars first formed 400 million years after the universe's creation.
- Discovered that the universe is made of up 4.4 percent ordinary matter or atoms, 22 percent invisible material known as dark matter, and 74 percent a mysterious entity known as dark energy.

## Staying Ahead of the Curve

### Principal Investigator Builds One of NASA's First UAV-Specific Instruments

To Goddard Principal Investigator Matt McGill, NASA's decision to ultimately replace many of its high-altitude research aircraft with unmanned aerial vehicles (UAVs) begged a very simple question: What instruments would be available to fly on these UAVs? Although NASA has built several remote-sensing instruments for manned aircraft, most do not fit within the constraints of a UAV platform.

Not content to wait for an answer, McGill applied for and received Goddard Internal Research and Development (IRAD) funding in FY 2005 and 2006 to construct a cloud-aerosol lidar instrument for use on a UAV. The instrument is based on the Center's highly successful Cloud Physics Lidar (CPL), an autonomous instrument used on the high-altitude ER-2 aircraft. Constructing a new version that would fit inside a UAV would allow NASA Earth scientists to continue gathering critical measurements of clouds and aerosols as the Agency transitioned to UAV platforms.



*Shane Wake, an employee with Goddard's Optics Branch, works with the original ER-2 Cloud Physics Lidar instrument as he prepares to assemble a similar instrument for use on unmanned aerial vehicles.*

Now being assembled, the new instrument will be available for flights this summer, McGill said. He's submitted a proposal to Headquarters under NASA's 2006 research announcement for UAV instrumentation. If awarded the task, he will integrate the instrument into the new Ikhana or Global Hawk UAV to gather data over the poles. In addition, the National Oceanic and Atmospheric Administration and the National Center for Atmospheric Research have expressed interest in using the instrument, he said.

"We saw a need and we went ahead and did something about it," McGill said. When NASA finally transitions to a UAV fleet, which is dependent on funding and construc-



*NASA's ER-2 aircraft fly a variety of high-altitude scientific payloads, including Goddard's Cloud Physics Lidar. When NASA transitions these craft to unmanned aerial vehicles, a Goddard scientist has created an instrument that can fly.*

tion of a command and control system, McGill says he'll be ready. "We're ahead of the curve. This is a wise investment for Goddard and for NASA."

The new instrument is a replica of the original, which made its maiden flight in a campaign to study the effects of biomass burning in southern Africa 6 years ago. From its berth inside the ER-2, which flies 65,000 feet above Earth's surface, CPL provided data on cloud height and the structure of aerosols and smoke plumes — data needed to better understand the interaction of Earth's land and atmosphere.

CPL obtained these measurements by transmitting pulses of three different wavelengths of light — near infrared, green, and near ultraviolet. The light scattered off substances in the atmosphere and a telescope then gathered the scattered light, passing it through to a photon-counting detector that revealed the composition of the atmosphere.

The measurements are useful not only for gathering scientific data, but also for validating measurements gathered by instruments flying aboard Earth-orbiting satellites. Researchers involved with NASA's Infrared Pathfinder Satellite Observation (CALIPSO), the Ice, Cloud, and Land Elevation Satellite (ICESat), and the Moderate Resolution Imaging Spectroradiometers (MODIS) flying on Terra and Aqua all have used CPL data to validate their measurements.

Although the new UAV instrument functions like the original, the mechanical interface is different to accommodate the UAV payload area, McGill said. In addition, McGill used NASA's Small Business Innovative Research (SBIR) program to contract with a local company to develop a low-power, autonomous, card-size computer system to store the data, an innovation that McGill calls a "major breakthrough."

"We leveraged funds from the IRAD program and SBIR," he said. "We couldn't have done this without either." ♦

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## Dust Busters...

*Continued from page 3*

moving line between lunar day and night. The transition between the two could create more complex and stronger electric fields, further accelerating the grains.

### Strong Electric Fields

And, indeed, that's what Berg's LEAM found in the mid 1970s. Although designed to measure hypervelocity micrometeorite impacts to the Moon, the instrument mostly detected charged dust traveling many hundreds of miles per hour primarily at the terminator. While scientists suspect that strong electric fields form at the terminator and are believed to accelerate the dust, they have not yet obtained critical correlated measurements in the active regions.

Knowing these measurements are even more relevant now that NASA is considering Shackleton Crater as a site for a lunar base. The crater is aligned with the terminator and is potentially exposed to this high-energy, highly variable dust for extended periods of time.

For astronauts, the situation will be made worse by the fact that they carry their own charge and will attract dust as they rove about the Moon. And because the grit is so adhesive, it doesn't simply brush off like commonplace house dust. It embeds itself into material, which means that it's easily tracked into living habitats.



*Dust covered astronaut Harrison Schmitt's spacesuit as he retrieved lunar samples during the Apollo 17 mission.*

In some sense, Farrell and his colleagues are acting as lunar "weather men," trying to understand, model, and predict the character of the dusty lunar exosphere. "Our knowledge of the lunar electrostatic environment is still limited," Farrell says. "An updated LEAM to answer some of these questions is what we need before we return astronauts on the Moon for long-duration stays." ♦

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## Goddard Tech Trends

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